Claims

CLAIMS TO INVENTION:

1. An automated package identification and measuring system, wherein an omni-directional laser scanning tunnel is used to read bar codes on packages entering the tunnel, while a package dimensioning subsystem is used to capture information about the package prior to entry into the tunnel.

2. An automated package identification and measuring system, wherein Laser Detecting And Ranging (LADAR-based) scanning methods are used to capture two-dimensional range data maps of the space above a conveyor belt structure, and two-dimensional image contour tracing methods are used to extract package dimension data therefrom.

3. An automated package identification and measuring system, wherein the package dimensioning subsystem is realized as a LADAR-based package imaging and dimensioning unit (i.e. subsystem) supported above the conveyor belt structure of the system.

4. An automated package identification and measuring system, wherein the LADAR-based imaging, detecting and dimensioning subsystem produces a synchronized amplitude-modulated laser beam that is automatically scanned across the width of the conveyor belt structure and, during each scan thereacross, detects and processes the reflected laser beam in order to capture a row of raw range (and optionally reflection-intensity) information that is referenced with respect to a polar-type coordinate system symbolically-embedded within the LASAR-based imaging, detecting and dimensioning subsystem.

An automated unitary-type package identification and measuring system (i.e. contained within a single housing or enclosure), wherein a scanning subsytem is used to read bar codes on packages entering the system, while a package dimensioning subsystem is used to capture information about the package prior to entry into the tunnel.
An automated package identification and measuring system, wherein Laser Detecting And Ranging (LADAR-based) scanning methods are used to capture two-dimensional range data maps of the space above a conveyor belt structure, and two-dimensional image contour tracing methods are used to extract package dimension data therefrom.

A unitary system, in which the scanning subsystem can be realized using either a holographic scanning mechanism, a 1D or 2D camera system or polygonal scanning mechanism.

A unitary system, in which the package velocity is computed by using a pair of laser beams projected aat different angular projections over the conveyor belt.

The unitary system in which the laser scanning lasers beams having multiple wavelengths to sensing packages having a wide range of reflectivity characteristics.

A system and method, in which the same amplitude modulated laser beam used to dimension packages is also used to detect the presence of packages over a prespecified time interval.

A system and method, wherein an omni-directional laser scanning tunnel is used to read bar codes on packages entering the tunnel, while a package dimensioning subsystem is used to capture information about the package prior to entry into the tunnel.

A package identification and measuring system, wherein Laser Detecting And Ranging (LADAR-based) scanning methods are used to capture two-dimensional range data maps of the space above a conveyor belt structure, and two-dimensional image contour tracing methods are used to extract package dimension data therefrom.

A package identification and measuring system, wherein the package dimensioning subsystem is realized as a LADAR-based package imaging and dimensioning unit (i.e. subsystem) supported above the conveyor belt structure of the system.

A package identification and measuring system, wherein the LADAR-based imaging, detecting and dimensioning subsystem produces a synchronized amplitude-modulated laser beam that is automatically scanned across the width of the conveyor belt structure and, during each scan thereacross, detects and processes the reflected laser beam in order to capture a row of raw range (and optionally reflection-intensity) information that is referenced with respect to a polar-type coordinate system symbolically-embedded within the LADAR-based imaging, detecting and dimensioning subsystem.

A package identification and measuring subsystem, wherein the rows of range data captured by the LADAR-based imaging, detecting and dimensioning subsystem are continuously

loaded into a preprocessing data buffer, one row at a time, and processed in real-time using window-type convolution kernals that smooth and edge-detect the raw range data and thus improve its quality for subsequent dimension data extraction operations.

A package identification and measuring subsystem, wherein the LADAR-based imaging, detecting and dimensioning subsystem automatically subtracts detected background information (including noise) from the continuously updated range data map as to accommodate for changing environmental conditions and enable high system performance independent of background lighting conditions.

A package identification and measuring subsystem, wherein the LADAR-based imaging, detecting and dimensioning subsystem automatically buffers consecutively captured rows of smoothed/edge-detected range data to provide a range data map of the space above the conveyor belt, and employs two-dimensional image contour tracing techniques to detect image contours within the buffered range data map, indicative of packages being transported through the laser scanning tunnel system.

A package identification and measuring subsystem, wherein the LADAR-based imaging, detecting and dimensioning subsystem automatically processes the indices (m,n) of the computed contours in order to detect vertices associated with polygonal-shaped objects extracted from the range data map, which are representative of packages or like objects being transported through the laser scanning tunnel system.

A package identification and measuring subsystem, wherein the LADAR-based imaging, detecting and dimensioning subsystem automatically processes the m and n indices of the detected vertices associated with the computed contours in order to detect candidates for corner points associated with the corners of a particular package being transported through the laser scanning tunnel system.

A package identification and measuring subsystem, wherein the LADAR-based imaging, detecting and dimensioning subsystem automatically processes the m and n indices of detected corner point candidates in order to reduce those corner point candidates down to those most likely to be the corners of a regular-shaped polygonal object (e.g. six sided box).

A system, wherein the tunnel scanning subsystem provided therein comprises a plurality of laser scanning subsystems, and each such laser scanning subsystem is capable of automatically generating, for each bar code symbol read by the subsystem, accurate information indicative of the precise point of origin of the laser scanning beam and its optical path to the read bar code symbol, as well as produced symbol character data representative of the read bar code symbol.

A system, wherein the plurality of laser scanning subsystems generated an omnidirectional laser scanning pattern within a 3-D scanning volume, wherein a bar code symbol applied to any one side of a six-sided package (e.g. box) will be automatically scanned and decoded when passed through the 3-D scanning volume using the conveyor subsystem.

A system, wherein the laser scanning subsystems comprise holographic laser scanning subsystems, and also polygonal-type laser scanning subsystems for reading bar code symbols facing the conveyor surface.

A system, wherein each holographic laser scanning subsystem employed in the tunnel scanning subsystem comprises a device for generating information specifying which holographic scanning facet or holographic facet sector (or segment) produced the laser scan data used to read any bar code symbol by the subsystem.

A system, wherein each non-holographic (e.g. polygonal-type and CCD camera type) laser scanning subsystem employed in the tunnel scanning subsystem comprises a device for generating information specifying which mirror facet or mirror sector produced the laser scan data used to read any bar code symbol by the subsystem.

A system, wherein the data element queuing, handling and processing subsystem provided therein further comprises a scan beam geometry modeling subsystem for producing, relative to a local coordinate reference system symbolically embedded within the laser scanning subsystem, coordinate information comprising a geometric model of each laser scanning beam used to read a particular bar code symbol for which symbol character data has been produced by the laser scanning subsystem.

A system, wherein the data element queuing, handling and processing subsystem provided therein further comprises a first homogeneous transformation module for converting the

coordinate information comprising the geometric model of each laser scanning beam used to read a particular bar code symbol on a detected package, from the local coordinate reference system symbolically embedded within the laser scanning subsystem, to a global coordinate reference system symbolically embedded within the tunnel-type scanning system.

A system, wherein the data element queuing, handling and processing subsystem provided therein further comprises a package surface modeling subsystem for producing, relative to a local coordinate reference system symbolically embedded within the laser scanning subsystem, coordinate information comprising a geometric model of each surface on each package detected by the package detection and dimensioning subsystem.

A system, wherein the data element queuing, handling and processing subsystem provided therein further comprises a second homogeneous transformation module for converting the coordinate information comprising the geometric model of each surface on a detected package, from the local coordinate reference system symbolically embedded within the laser scanning subsystem, to a global coordinate reference system symbolically embedded within the tunnel-type scanning system.

A system, wherein a laser scan beam and package surface intersection determination subsystem is provided for determining which detected package was scanned by the laser scanning beam that read a particular bar code symbol, and for linking (i.e. correlating) package measurement data associated with the detected package with package identification data associated with the laser scanning beam that read a bar code symbol on a detected package.

A system with a package velocity measurement subsystem for measuring the velocity of the package as it moves from the package detection and dimensioning subsystem through the laser scanning tunnel subsystem of the system.

A system, wherein the package velocity measurement subsystem is realized as an integral part of the LADAR-based imaging, detecting and dimensioning subsystem.

A system, wherein a package weighing-in-motion subsystem is provided for weighing singulated packages moving through the package detection and dimensioning subsystem, and producing weight measurement information for assignment to each detected package.

A package identification and measuring system, wherein singulated packages can be detected, dimensioned, weighed, and identified in a fully automated manner without human intervention, while being transported through a laser scanning tunnel subsystem using a package conveyor subsystem.

Another object of the present invention is to provide such a system, wherein the tunnel scanning subsystem provided therein comprises a plurality of laser scanning subsystems, and each such laser scanning subsystem is capable of automatically generating, for each bar code symbol read by the subsystem, accurate information indicative of the precise point of origin of the laser scanning beam and its optical path to the read the bar code symbol, as well as symbol character data representative of the read bar code symbol.

Another object of the present invention is to provide such a system, wherein the data element queuing, handling and processing subsystem provided therein further comprises a scan beam geometry modeling subsystem for producing, relative to a local coordinate reference system symbolically embedded within the laser scanning subsystem, coordinate information comprising a geometric model of each laser scanning beam used to read a particular bar code symbol for which symbol character data has been produced by the laser scanning subsystem.

Another object of the present invention is to provide such a system, wherein the data element queuing, handling and processing subsystem provided therein further comprises a first homogeneous transformation module for converting the coordinate information comprising the geometric model of each laser scanning beam used to read a particular bar code symbol on a detected package, from the local coordinate reference system symbolically embedded within the laser scanning subsystem, to a global coordinate reference system symbolically embedded within the tunnel-type scanning system.

Another object of the present invention is to provide such a system, wherein the data element queuing, handling and processing subsystem provided therein further comprises a package surface modeling subsystem for producing, relative to a local coordinate reference system symbolically embedded within the laser scanning subsystem, coordinate information comprising a geometric model of each surface on each package detected by the package detection and dimensioning subsystem.

Another object of the present invention is to provide such a system, wherein the data element queuing, handling and processing subsystem provided therein further comprises a second homogeneous transformation module for converting the coordinate information comprising the geometric model of each surface on a detected package, from the local coordinate reference system symbolically embedded within the laser scanning subsystem, to a global coordinate reference system symbolically embedded within the tunnel-type scanning system.

Another object of the present invention is to provide such a system, wherein a laser scan beam and package surface intersection determination subsystem is provided for determining which detected package was scanned by the laser scanning beam that read a particular bar code symbol, and for linking (i.e. correlating) package measurement data associated with the detected package with package identification data associated with the laser scanning beam that read a bar code symbol on a detected package.

Another object of the present invention is to provide such a system with a package velocity measurement subsystem for measuring the velocity of the package as it moves from the package detection and dimensioning subsystem through the laser scanning tunnel subsystem of the system.

Another object of the present invention is to provide such a system, wherein the package detection and dimensioning subsystem provided on the input side of the laser scanning tunnel subsystem comprises a laser scanning mechanism that generates an amplitude modulated laser scanning beam that is scanned across the width of the conveyor structure in the package conveyor subsystem while the scanning beam is disposed substantially perpendicular to the surface of the conveyor structure, and light reflected from scanned packages is collected, detected and processed to produce information representative of the package height profile across the width of the conveyor structure for each timing sampling instant carried out by the package detection and dimension subsystem.

Another object of the present invention is to provide a LADAR-based package imaging, detecting and dimensioning subsystem for imaging and/or profiling packages transported thereby a substantially constant velocity..

Another object of the present invention is to provide such a LADAR-based imaging, detecting and dimensioning subsystem, wherein a synchronized amplitude-modulated laser beam is automatically produced and scanned across the width of a conveyor belt structure

and, during each scan thereacross, detects and processes the reflected laser beam in order to capture a row of raw range (and optionally reflection-intensity) information that is referenced with respect to a polar-type coordinate system symbolically-embedded within the LASAR-based imaging, detecting and dimensioning subsystem.

Another object of the present invention is to provide such a LADAR-based imaging, detecting and dimensioning subsystem, wherein captured rows of range data are continuously loaded into a preprocessing data buffer, one row at a time, and processed in real-time using window-type convolution kernals that smooth and edge-detect the raw range data and thus improve its quality for subsequent dimension data extraction operations.

Another object of the present invention is to provide such a LADAR-based imaging, detecting and dimensioning subsystem, wherein detected background information (including noise) is automatically subtracted from consecutively captured rows of smoothed/edge-detected range data to provide a range data map of the space above the conveyor belt, for use in carrying out package dimension data extraction operations involving the same.

Another object of the present invention is to provide such a LADAR-based imaging, detecting and dimensioning subsystem, wherein two-dimensional image contour tracing techniques are used to detect image contours within the buffered range data map, indicative of packages being transported thereby.

Another object of the present invention is to provide such a LADAR-based imaging, detecting and dimensioning subsystem automatically processes the indices (m,n) of the computed contours in order to detect possible vertices associated with polygonal-shaped objects extracted from the range data map, which are representative of packages or like objects being transported by the subsystem.

Another object of the present invention is to provide such a LADAR-based imaging, detecting and dimensioning subsystem, wherein the m and n indices of the vertices associated with the computed contours are automatically processed in order to detect candidates for corner points associated with the corners of packages transported by the subsystem.

Another object of the present invention is to provide such a LADAR-based imaging, detecting and dimensioning subsystem, wherein the m and n indices of detected corner point candidates are automatically processed in order to reduce those corner point candidates down to those most likely to be the corners of a regular-shaped polygonal object (e.g. six sided box).

Another object of the present invention is to provide such a LADAR-based imaging, detecting and dimensioning subsystem, wherein the m and n indices of the corner points extracted from the range data map are automatically processed in order to compute the surface area of the package represented by the contours traced therein.

Another object of the present invention is to provide such a LADAR-based imaging, detecting and dimensioning subsystem, wherein the m and n indices of the corner points extracted from the range data map are automatically processed in order to compute the x,y and z coordinates corresponding to the corners of the package represented by the contours traced therein, referenced relative to a Cartesian-type global coordinate reference system symbolically embedded within the automated package identification and measuring subsystem.

Another object of the present invention is to provide such a LADAR-based imaging, detecting and dimensioning subsystem, wherein the m and n indices of the corner points extracted from the range data map are automatically processed in order to compute the average height of the package represented by the contours traced therein, referenced relative to the Cartesian-type global coordinate reference system.

Another object of the present invention is to provide such a LADAR-based imaging, detecting and dimensioning subsystem, wherein a polygonal-type laser scanning mechanism is used to scan an amplitude-modulated laser beam across the width of the conveyor belt.

Another object of the present invention is to provide such a LADAR-based imaging, detecting and dimensioning subsystem, wherein a holographic-type laser scanning mechanism is used to scan an amplitude-modulated laser beam across the width of the conveyor belt.

A dual-beam LADAR-based imaging, detecting and dimensioning subsystem integrated within the housing of a unitary package identification and dimensioning system.

A dual-beam LADAR-based imaging, detecting and dimensioning subsystem comprising retro-reflective beam-steering mirrors for mounting on opposite sides of a conveyor belt.

A dual-beam LADAR-based imaging, detecting and dimensioning subsystem of the present invention, comprising:

an multi-sided polygonal scanning element, mounted on an optical bench within the subsystem housing, for generating a pair of amplitude modulated laser beams (from a pair of

laser beam production modules) which are projected along a pair of spaced-apart scanning planes through a light transmission aperture formed in the subsystem housing, a light collecting mirror mounted on the optical bench for collecting reflected laser light off a scanned object (e.g. package) and focusing the same to a focal point located on the surface of a stationary planar mirror mounted on the optical bench, and an avalanche-type photodetector mounted on the optical bench for detecting laser light focused onto the stationary planar mirror and producing an electrical signal corresponding thereto, signal processing circuitry for processing the produced electrical signal and generating raw digital range data representative of the distance from the polygonal scanning element to sampled points along the scanned object (as well digital scan data representative of any bar code symbol the scanned surface of the object), and a programmed digital image data processor for preprocessing the raw digital range data and removing background information components, and for processing the preprocessed range data so as to extract therefrom information regarding the dimensions (e.g. area, height, length, width and vertices) of the scanned object and produce data representative thereof as well as the velocity of the dimensioned package.

A dual-beam LADAR-based imaging, detecting and dimensioning subsystem comprising:

means for producing a pari of laser scanning beams for projection through a holographic spatial filter causing a plurality of modulated laser beams to be simultaneously projected over the conveyor belt surface at different angular spacings to achieve a desired degree of spatial sampling of the conveyor belt surface and objects transported therealong, while a rotating eight-sided polygon scanning element is used to created a moving field of view (FOV) across the illuminated conveyor belt.

A dual-beam LADAR-based imaging, detecting and dimensioning subsystem comprising:

a holographic scanning disc, rotatably mounted on an optical bench within the subsystem housing, for generating a pair of amplitude modulated laser beams having multi-wavelengths (produced from a pair of laser beam production module) and projected along a pair of spaced-apart scanning planes (along multiple depths of focus) through a light transmission aperture formed in the subsystem housing, a parabolic light collecting mirror mounted beneath the holographic scanning disc for collecting reflected laser light off a scanned object (e.g. package) and focusing the same to an avalanche-type photodetector mounted above the scanning disc, and producing an electrical signal corresponding thereto,

signal processing circuitry for processing the produced electrical signal and generating raw digital range data representative of the distance from the polygonal scanning element to sampled points along the scanned object (as well digital scan data representative of any bar code symbol the scanned surface of the object), and a programmed digital image data processor for preprocessing the raw digital range data and removing background information components, and for processing the preprocessed range data so as to extract therefrom information regarding the dimensions (e.g. area, height, length, width and vertices) of the scanned object and produce data representative thereof as well as the velocity of the dimensioned package.

A dual-beam LADAR-based subsystem comprising:
a mechanism for generating a pair of laser scanning for projection perpendicular to the surface of a conveyor belt along the entire length thereof, using a cylindrical-type focusing element (i.e. cylindrical holographic optical element HOE).

A package-in-the-tunnel (PITT) indication subsystem comprising:

a LADAR-based imaging, detecting and dimensioning subsystem, wherein the extreme portion of one of the amplitude modulated (AM) laser scanning beams produced by said LADAR-based imaging, detecting and dimensioning subsystem is used to generate an object sensing beam is reflected across the width of the conveyor belt of the system, is reflected off a mirror on the opposite side of the conveyor belt, and is detected at a prespecified "time window" and processed in effort to detect the presence or absence of packages being transported along the conveyor belt.

A method of package (i.e. object) detection along a conveyor belt using a portion of the amplitude-modulated laser scanning beam generated by the LADAR-based imaging, detecting, and dimensioning subsystem of the present invention.

A method of deriving from a selected portion of a AM laser scanning beam generated by the LADAR-based subsystem of the present invention, and a time-windowed portion of which is digitally processed by a FIR-type digital filter so as to compute a first derivative signal thereof which is then compared against threshold values to determine whether or not a package is present or absent from the conveyor belt over the time period (i.e. time window) of interest,

A LADAR-based imaging, detecting and dimensioning subsystem comprising a start-of-object-sensing cycle (SOSC) pulse generation circuit; a LADAR-based photo-detection circuit; an analog object detection circuit; and controller circuit with object detection window signal generation capabilities.

The system above wherein said analog object detection circuit performs a first derivative function on the analog intensity varying object sensing signal over a prespecified/controlled time period (i.e. time-window), and thresholds the first derivative signal to determine whether or not an package is present or absent from the conveyor belt over the time-window and generates a digital output signal to indicate the state of such determinations.

A tunnel-type laser scanning package identification and weighing system ccomprising:

a high speed conveyor belt;

a LADAR-based imaging, detecting and dimensioning subsystem; AND and AN automatic bar code symbol reading system employing a 1-D (i.e. linear) CCD-based scanning array below which a light focusing lens is mounted for imaging bar coded packages transported therebencath and decode processing to read such bar code symbols in a fully automated manner without human intervention.

An automated tunnel-type laser scanning package identification and weighing system comprising:

a high speed conveyor belt;

a LADAR-based package imaging, detecting and dimensioning subsystem,

a low-resolution CCD camera to locate the x,y position of labels on scanned packages;

an automatic bar code symbol reading system comprising a stationarily-mounted light focusing lens mounted below a vertically-translatable 2-D CCD-based high-resolution scanning array controlled by package height information obtained from the LADAR-based package imaging, detecting and dimensioning subsystem; and

a pair of orthogonally-mounted field-of-view (FOV) steerable mirrors mounted beneath the 2-D CCD-based scanning array and controlled by the x,y coordinates collected by the low-resolution CCD camera, so as to scan detected package labels, collect high-resolution scan data therefrom, and decode processing the same so as to read bar code